1. INTRODUCTION

The U.S. Environmental Protection Agency (EPA) is charged with protecting human health from adverse effects resulting from exposure to contaminants in the environment. EPA estimates risk to human health by conducting risk assessments, as illustrated in Figure 1-1. An important step in risk assessment is exposure assessment (U.S. EPA, 1992a). The process of exposure assessment involves (1) identification of potential exposure pathways, (2) quantification of chemical intakes/potential doses, and (3) identification/estimation of the exposed population (U.S. EPA, 1992a). This document addresses the third component of an exposure assessment, estimation of the magnitude of the exposed population. It does not address the duration or degree to which a population is exposed to a contaminant(s) of concern. Duration and degree of exposure and other aspects of exposure assessment are presented in *Exposure Factors Handbook* (1997).

A primary goal of risk assessment is to develop a distribution of the range of exposures/risks occurring in the exposed population. In the past, some risk assessments did not characterize the subsets of the exposed population with higher than average exposures/risks. Individual populations can experience greater risk than the general population through higher than average exposure and/or higher than average biological sensitivity. An important limitation in the scope of this document is that it addresses populations who are potentially at greater risk due to high exposure, but not populations with greater risks due to biological sensitivity.

The data and population subsets presented are not intended to be comprehensive or prescriptive. This document does not include all possible populations and does not include guidance for identifying and enumerating all populations under every circumstance. The inclusion of a specific population in this document is not intended to imply that all members of a specific population addressed are more likely than the general population to experience potentially high exposures to a given contaminant.

The specific goals of this document are to (1) help assessors identify potentially highly exposed populations and (2) help assessors estimate the size of these populations. It provides information on the number of individuals or the percent of the general population associated with

dietary preferences, cultural practices, geographic location and setting (i.e., urban vs. rural), and other activities that target populations and individuals as possibly highly exposed candidates. The literature summaries provided are not all-inclusive, but are meant to provide the reader with a general overview of population data reported in recent literature. In most cases, data are from government publications, peer-reviewed literature, and trade associations. Data are presented as they appear in the original studies/reports. No attempt was made to verify or assess the quality of the data beyond what is described in the published reports. Within the constraint of presenting the original material as accurately as possible, terminologies used to describe areas such as racial populations and study results are those presented by the study authors.

The *Exposure Factors Handbook* was first published in 1989 (U.S. EPA, 1989a). The revised handbook was published in 1997. This document is intended to be used in conjunction with the revised *Exposure Factors Handbook* (U.S. EPA, 1997). The handbook provides statistical data on human characteristics and behaviors used in assessing exposure (e.g., ingestion rates of foods, activity duration and frequency, soil ingestion rates, body weight, skin surface area), addressing the second component of the exposure assessment process mentioned above. It focuses primarily on exposure factors pertaining to the general population but also presents, where possible, data specific to various age, gender, racial or ethnic, and occupational subgroups. The procedure for using these two documents in combination is as follows:

- An assessor will use this document to help determine if potentially highly exposed populations may exist in the area of interest and to estimate the size of such groups.
- Once the suspected potentially highly exposed populations are identified, the assessor can then use the *Exposure Factors Handbook* (U.S. EPA, 1997) to select intake and other exposure factor values specific to the groups identified above. These exposure factor values would be combined with site-specific information on environmental concentrations of contaminants to estimate exposure levels.

Other related documents that assessors may find helpful for identifying and evaluating highly exposed populations include, but are not limited to, the following: *Methods for Enumerating and Characterizing Populations Exposed to Chemical Substances* (U.S. EPA, 1985); *Populations of*

Potential Concern in Chemical Exposure and Risk Assessment (U.S. EPA, 1989b); and *Risk Assessment Guidance for Superfund*, Volume 1 (U.S. EPA, 1989c).

Although multitudes of anecdotal and circumstantial evidence suggest that a particular subgroup may be more susceptible than other members within the general population, very little direct evidence exists of what the actual exposures and risk levels are for specific chemicals or physical agents in the environment. Therefore, the data presented in this document for various subgroupings do not imply or necessitate that all or any members of a given group are highly exposed. The data contained in this document should be used as a tool to alert the assessor to subgroups that may potentially experience greater exposures than the general population. The data also should be used to help the assessor determine the number of individuals who potentially may be subjected to increased exposures. When possible, assessors are encouraged to collect site-specific data to help confirm if any groups are experiencing high exposures.

1.1. TERMINOLOGY USED TO DEFINE CONCEPTS RELATING TO EXPOSURE

1.1.1. Exposure

The *Guidelines for Exposure Assessment* define exposure as "the contact of an organism with a chemical or physical agent" (U.S. EPA, 1992a). The document further defines exposure as "contact of a chemical, physical, or biological agent with the outer boundary of an organism." Exposure is quantified as the concentration of the agent in the medium in contact integrated over the time duration of that contact (U.S. EPA, 1992a).

1.1.2. High End, Upper End, Exposure Distribution

A goal of many exposure assessments is to estimate the complete range of exposures occurring in the exposed population and number of people at each exposure level. This concept can be illustrated graphically by a distribution curve showing numbers of people exposed at various levels. Note: persons in the high end of the health risk distribution are not necessarily the same individuals as those in the high end of the exposure distribution (U.S. EPA, 1992a). Individuals represented within what is known as the "upper end" or "high-end" of an exposure distribution are referred to as highly exposed individuals. A high-end exposure estimate is defined

in the *Guidelines for Exposure Assessment* as “a plausible estimate of individual exposure or dose for those persons at the upper end of an exposure or dose distribution, conceptually above the 90th percentile, but not higher than the individual in the population who has the highest exposure” (U.S. EPA, 1992a).

1.1.3. Susceptibility, Highly Exposed, Biologically Sensitive

Definitions for “susceptibility,” “highly exposed,” and “sensitivity” vary according to various professions. For example, toxicologists refer to individuals who respond to the lowest concentrations of a given toxicant as "susceptible" (Hattis et al., 1987). Genetic epidemiologists define susceptible individuals as those who become ill (Khoury et al., 1989). EPA has used the term "susceptible" to refer to both highly exposed and biologically sensitive individuals. An informal survey conducted within EPA showed that many investigators considered susceptible populations to be either sensitive or highly exposed (Grassman, 1995). However, the terms "highly exposed" and "sensitive" are quite different and are not used interchangeably in this document. For example, if a population showing heightened sensitivities towards a particular toxic agent experiences little contact with that agent, the overall risk in this instance could be very low. Conversely, a population with sensitivities similar to those of the general population can be at greater risk if it experiences greater contact with toxic agents.

Individuals are “highly exposed” on the basis of their activities, preferences, and behavior patterns that differ from those established for the general population. For example, high exposure could relate to food choices, frequency of foods consumed, cultural practices, geographic location, residential setting (urban vs. rural), occupation, education, socioeconomic status, proximity to hazardous facilities, and activity patterns. These parameters may vary according to seasonal aspects, age, and other factors.

A “sensitive” individual is one who shows an adverse effect to a toxic agent at lower doses than the general population or who shows more severe or more frequent adverse effects after exposure to similar amounts of a toxic agent as the general population. For example, the fetus is more sensitive to many chemicals than older individuals. Biological sensitivity may result from

age (Calabrese, 1986), gender (Calabrese, 1985), genetics (Omenn, 1984), deficiencies relating to diet and health, or other factors (Rios et al., 1993; Calabrese, 1986).

Figure 1-2 presents the Methodological Approach for Identification and Evaluation of Populations Potentially at Greater Risk. The figure illustrates that populations are potentially at greater risk when they are "more exposed" or "more susceptible" (Sexton et al., 1993). The scope of this document, however, does not include identifying biologically sensitive populations or determining one's susceptibility (or sensitivity) to a chemical. Rather, it examines how activities or behaviors can subject particular segments of the population to greater exposures and more frequent contact with environmental contaminants.

1.2. IDENTIFYING THE POTENTIALLY HIGHLY EXPOSED POPULATION

As discussed previously, one objective of this document is to help assessors identify potentially highly exposed populations. This section summarizes the types of information presented that address this issue. Although the topic is beyond the scope of this document, some discussion is included on how these factors relate to biological sensitivity. These discussions are included as important related issues that assessors can pursue from other sources. Assessors are reminded that if an individual (or population) is exposed to environmental compounds, it does not necessarily result in that individual (or population) being highly exposed relative to the general population.

The fact that data for a particular subgroup are presented does not mean that all members within that subgroup are highly exposed or that such exposure constitutes a high risk. Also, this document does not include all possible groupings of susceptible populations. Direct cause-and-effect relationships are not being claimed; rather, information is presented that has the potential for demonstration of correlations between exposure and the incidence and severity of symptomatic effects. Some of the important factors for identifying potentially highly exposed populations are chemicals of concern, age, gender, and lifestyle. Therefore, these areas are addressed in the following sections of this document.

1.2.1. Chemical(s) of Concern

Identification and characterization of specific chemicals of concern are necessary steps in identifying and enumerating populations with high-end exposures. For example, a chemical classified as a pesticide would prompt assessors to consider populations working in an agriculturally related occupation or people who participate in gardening as possible candidates for receiving higher exposures to pesticides (further discussed in Sections 1.2.3 and 7.4). Because of its prevalence in the environment, lead is another chemical of concern that can be associated with various conditions and groups. For example, older houses often have lead-based paints (Sutton et al., 1995; Barltrop, 1965) (Section 4.1 and Table 4-3). Soils near roadways (Romieu et al., 1995) (Section 3.6) tend to have elevated lead levels from the previous use of lead in gasoline. Not only is lead a chemical to which children are biologically more sensitive than adults, but it is also a chemical that children are more likely to be exposed to because of the prevalence of certain activities in children (ILSI, 1992) such as pica. Pica is defined as the intentional ingestion of nonfood items (Bruhn and Pangborn, 1971; Vermeer and Frate, 1979; NRC, 1993). Children exhibiting pica may experience exposures to lead from ingestion of paint chips and lead-contaminated soils. Thus, children are a population who should be recognized as having possibly higher exposures to lead and other chemicals from ingestion. Additional examples of populations potentially more exposed to specific environmental agents than the general population are presented in Table 1-1. This table is not intended to be comprehensive. Rather, it is presented to show possible examples of chemical-specific population exposures.

1.2.2. Age

The age of the population should be considered when estimating exposure. For example, nursing infants could potentially have more exposure (per unit body weight) to some lipophilic contaminants than the general population through ingestion of breastmilk containing these contaminants. Lipophilic compounds such as pesticides and dioxins have commonly been identified in human milk (NAS, 1991; NRC, 1993). The levels of these compounds in human milk vary with duration of lactation, number of children nursed, and the weight of the nursing mother (NAS, 1991).

Young children may have an increased potential for exposure to soil contaminants as a result of pica and mouthing behaviors. The relatively higher ratio of surface area to body weight of fetuses, neonates, and children, as compared to adults, may result in children being exposed to higher concentrations of chemical per unit body weight than adults (Wester and Maibach, 1982).

Age also can be used to identify biologically sensitive individuals. The effect of age sensitivity to contaminant exposure will vary with the substance (Calabrese, 1986). For example, although sensitivity to skin irritants generally decreases with age, renal function also decreases with age, thereby increasing sensitivity to chemicals that affect kidneys (Calabrese, 1986). Thus, children tend to be more resistant than adults to the harmful effects of renal toxicants (Calabrese, 1986). In addition, adults more than 50 years old generally have a decreased capacity to detoxify and/or excrete some chemical substances, and also exhibit a functional decline in the immune system (Calabrese, 1986). The fetus, in comparison to older individuals, is more sensitive to many chemicals. For example, the developing nervous system of the fetus or neonate has increased susceptibility to the neurotoxic effects of lead (ATSDR, 1992). In addition, children at various stages of development are also more sensitive to exposure to chemicals because of the immaturity of their enzyme detoxification and immune systems (Calabrese, 1986; Lorenz and Kleinman, 1988; NRC, 1993; Gladkte and Heimann, 1975).

Age demographics for the general U.S. population are presented in Section 2. Age-related activities are discussed in Sections 8 and 9.

1.2.3. Gender

Gender-related behavior and activity patterns also can increase an individual's exposure to toxic agents (Behrman et al., 1987). For example, during pregnancy some women may have increased food consumption because of increased nutritional need and thus can have increased exposure to any toxic contaminant present on or in a food sources. Additionally, pica is practiced by some women during pregnancy and most often involves the consumption of dirt or clay (Neuhauser, 1994). These substances may be contaminated with chemical/toxic compounds.

Gender-related economic factors, specifically those related to living in low-income households, can increase an individual's potential exposure to toxic agents (NRC, 1993;

Starfield, 1982; Mitchell and Dawson, 1973; Starfield and Budetti, 1985; CDHS, 1991). Data presented in Table 10-4 of this document show that for each year studied (1966-1994), a greater percentage of women than men live in poverty (U.S. Bureau of the Census, 1995).

Participation in certain occupations can also increase an individual's exposure to toxic agents. For example, men comprise between 75% and 80% of workers in the farming industry (U.S. DOL, 1994); therefore, they may be exposed more frequently than women to agricultural pesticides. Women comprise more than 90% of workers in the cleaning industry (U.S. DOL, 1994); therefore, women have the potential for more frequent exposure than men to chemicals contained in cleaning products. Occupational data by gender are presented in Section 7 of this document.

Although sex-linked differences in sensitivities to toxic chemicals have not been investigated extensively, the gender differences observed for several toxic substances have been attributed to such factors as differential gastrointestinal absorption (Adrian et al., 1986), plasma protein binding (Rane et al., 1971; Morselli et al., 1980; Morselli, 1989), biliary excretion (Lorenz and Kleinman, 1988; NRC, 1993), tissue distribution (NRC, 1993; Morselli, 1980), and enzymatic bioactivation/detoxification activities (NRC, 1993; Greengard, 1977). With regard to a sensitive population, neither sex universally can be labeled more sensitive or less sensitive to all substances. However, because of the physiological changes (e.g., a marked increase in the requirement for calcium and iron, hormonal alterations, respiratory disease susceptibility) that occur during pregnancy, pregnant women may be predisposed to the toxic effects of such chemicals as beryllium, lead, manganese, and organophosphate insecticides (Romero et al., 1989; Neuhauser, 1994).

1.2.4. Lifestyle, Behavior, and Social Structure

The fact that exposure to a pollutant may be determined, in part, by the behavior of the receptor (i.e., human) is a basic principle of exposure assessment. The risk potential is increased by a behavior that may not place a person in direct contact with a particular pollutant, but nevertheless makes them more susceptible to the pollutant’s effects when exposure to that pollutant does occurs. For example, smoking enhances the toxicity of other chemicals by

restricting airway conductance or making it more difficult to clear volatiles from the lungs (Klaassen et al., 1996). Excessive consumption of alcohol appears to interfere with the detoxification enzyme system of the liver (Klaassen et al., 1996).

Another example of increased risk due to behavioral practices is the use of metallic mercury for medicinal and religious practices in Caribbean and Hispanic populations. Mercury sprinkled on the floor or carpet could result in potentially increased exposure (dermal, inhalation, and ingestion) to mercury for these specific populations (Wendroff, 1990).

Other activities that may lead to individuals having potentially greater than average exposure to pollutants include breastfeeding, normal outdoor play for children, gardening and the consumption of homegrown foods, dirt biking, fishing, and hunting. The potentially highly exposed populations may include groups defined by ethnic origin, race, geographic region of residence, income level, or other demographic factors. Exposure/risk among these populations may differ from that of the general population as a result of behavioral or cultural factors (i.e., ethnic-related activities/traditions, geographic/regional behaviors, or social activities that may contribute to higher risk such as smoking or alcohol or drug use).

1.2.5. Personal Health

An individual's personal health can affect the extent to which they experience adverse effects upon exposure to environmental pollutants. Elements of personal health such as nutritional status, disease history, body weight, body fat, preexisting medical conditions, or genetic predispositions can exacerbate health consequences for individuals exposed to any environmental contaminant. For example, a person with asthma may experience respiratory problems after exposure to a respiratory irritant. This exposure could lead to a potentially life-threatening asthma attack, while a person not afflicted with asthma could experience only minor reactions (Calabrese, 1978). The authors note that issues related to personal health are of potential concern for the exposure/risk assessor; however, addressing potentially susceptible or highly exposed populations based on health concerns is beyond the scope of this document. The reader is referred to the following reference sources for information available on this subject: Calabrese, 1978; Kuczmarski, 1994; CDC, 1994; Montgomery and Carter-Pokras, 1993; Otten et

al., 1990; Rios et al., 1993; U.S. Bureau of the Census, 1995; and Weiss et al., 1992. Full citations are presented in Section 1.6. It should be noted that the references mentioned above are not intended to be all-inclusive, but are presented as examples of available sources addressing health concerns.

1.3. ENUMERATION OF VARIOUS HIGHLY EXPOSED POPULATIONS

A major difficulty encountered in the preparation of exposure assessments is the enumeration and characterization of specific populations exposed to chemical substances. The EPA Office of Toxic Substances 1985 document *Methods for Enumerating and Characterizing Populations Exposed to Chemical Substances* (U.S. EPA, 1985) presents methods and supporting information for enumerating and characterizing populations exposed to chemical substances in each of several exposure categories. Risk assessors should refer to this document for guidance in enumerating populations where site-specific data are not available. The categories of exposed populations addressed are as follows:

- Populations exposed to chemical substances in the ambient environment (all media);
- Populations exposed to chemical substances in the occupational environment;
- Populations exposed to chemical substances via the ingestion of foods;
- Populations exposed to chemical substances via the use of consumer products; and
- Populations exposed to chemical substances via the ingestion of drinking water.

All printed census information is available for purchase through the Government Printing Office (GPO). Other forms of information such as computer tapes, microfiches, maps, and technical documentation can be obtained from the U.S. Department of Commerce, Bureau of the Census.

The Census of Population is the major source for the size, distribution, and demographic characteristics of a geographically defined population. These include detailed characteristics such as age, sex, enumeration of various ethnic groups, and characterization of socioeconomic data.

Not all the population data required to assess highly exposed populations can be obtained from census data. For example, enumeration of populations who are potentially sensitive to contaminant exposure on the basis of personal health factors (preexisting diseases, allergies, or genetic predispositions) cannot be ascertained from census data. These data can sometimes be obtained from local government sources, health agencies, or references from medical journals. (See Table 11-1 for sources of local data.) Likewise, for enumeration of populations with high-risk behavior patterns, such as subsistence fishers, assessors may turn to surveys, State government agencies, or ethnographic field techniques (interviews, oral histories, etc.).

1.3.1. Framework of Methods

The framework for enumerating and characterizing exposed populations is the same for each population of interest and is comprised of three stages (U.S. EPA, 1985):

1. The identification of the exposed population.
2. The enumeration of the exposed population.
3. The characterization of the exposed population according to age, sex, and other demographics.

Figure 1-3 is a flow diagram of the three-stage framework. The first stage involves determining the site locations of the chemical/pollutant of concern from various sources in the environment. The people living at or near these locations can be identified via mapping techniques, site visits, aerial photographs, etc. These tools also can be used to estimate the number of people exposed to various chemicals in the environment. As an example, contaminant concentration isopleths can be plotted on a population density map, and the number of people within a given area of equal chemical concentration can be determined. The final step is to examine the exposed populations to determine the highly exposed populations. The application of this process to specific exposure scenarios is discussed as follows.

1.3.2. Contact With Chemicals in the Ambient Environment (All Media)

Populations potentially exposed to a chemical substance in the ambient environment can be identified through an evaluation of the substance's sources, its behavior in the environment, location of the source, and applicable monitoring data. Populations may be further defined by their participation in specific activities (i.e., occupation, exercise, hobbies, etc.) leading to exposure, and by demographics (age and gender).

1.3.3. Chemical Contact Resulting From Disposal Activities

Exposures resulting from disposal and transportation-related spills of chemical substances are types of exposures occurring in the ambient environment (all media). Populations exposed to chemical substances in these categories are identified either by geographic location or by occupation if site-specific data are not available.

1.3.4. Chemical Contact in Occupational Setting

The enumeration of occupationally exposed populations relies on the direct utilization and combination of numerous databases. This information is largely the result of efforts by the Federal Government (e.g., National Institute for Occupational Safety and Health [NIOSH] and Occupational Safety and Health Administration [OSHA]) to monitor employment and worker practices. The age and sex of a worker can affect physiological parameters that determine exposure (e.g., breathing rate, skin surface area) in the work environment. In addition, detailed exposure assessments may require that populations be described by age and sex distributions.

1.3.5. Ingestion of Chemicals in Foods

Foods and food products have geographic distributions and processing patterns that fluctuate depending on seasonal demand, availability, and personal preference. The population exposed to contaminants found in various foods and other products can be enumerated using information on the size of the consuming population in conjunction with information on the amount of food contamination. One approach for determining the size of the consuming

population is to divide the total amount of food consumed (for a particular food category or subset that is contaminated) by the average per-person or per-household ingestion rate.

1.3.6. Contact With Contaminants in Consumer Products

The identification and enumeration of populations exposed to chemical substances via the use of consumer products necessitates a listing of all products containing the chemical in question. The data needed to compile such a list can be derived from the materials balance for the chemical of concern and through literature searches. Other data sources are governmental agencies (e.g., Consumer Product Safety Commission [CPSC], industry fact sheets, and product labels). The potentially exposed population may be estimated using sources such as consumer product use surveys, which indicate what fraction of the total population uses a particular product or the characteristics of the population that uses the product (i.e., gender or age). Also, exposed population estimates may be made by using total number of products sold divided by the average number of products used per household. The age and sex of the exposed consumers affect the physiological parameters that determine exposure; they also identify sensitive populations. Detailed exposure assessments may require that populations be described by age and sex distribution.

1.3.7. Ingestion of Chemicals in Drinking Water

Identification of populations exposed to chemical substances via the ingestion of drinking water involves examining the sources of the chemical substance. Enumeration involves the use of local information or various computerized databases that contain information on drinking water, such as the sources of the raw water supply, intake locations, treatment methods, and populations served.

1.4. HOW TO USE THIS DOCUMENT

This document was prepared to assist risk assessors and other scientists in identifying subsets of the general population who might experience more frequent contact with, and greater exposures to, environmental contaminants than the general population. The first example presents

a theoretical description of how to use this document. The two scenarios presented at the end of this section illustrate how the tables and figures in this document can be used in conjunction with the *Exposure Factors Handbook* to characterize potentially highly exposed populations. These examples are not intended to be a complete analysis, but are for illustrative purposes only. Reference tables other than ones provided in the example scenarios may be appropriate, as determined by the assessor.

1.4.1. Examples of Exposure Scenarios

The information presented in this section explains how to use this document. The second example is less detailed and only refers the reader to specific tables for analysis.

1.4.2. Identifying Potentially Highly Exposed Population on the Basis of Exposure Pathway

Table 1-2 presents examples of identifying potentially highly exposed population based on exposure pathway. The sample exposure pathways presented are included as examples only, and are not presented as being the most likely pathways by which populations may be exposed.

1.4.3. Identifying Potentially Highly Exposed Population on the Basis of Chemical/Contaminant

Table 1-3 presents examples of identifying potentially highly exposed population based on chemical or contaminant of concern. The 15 contaminants listed in the table are taken from the 1997 Agency for Toxic Substances and Disease Registry (ATSDR)/EPA's Priority List of Hazardous Substances: 1997. The information is from the ATSDR web site, available at the following Internet address: *http://atsdr1.atsdr.cdc.gov:8080/cxcx3.html*. The contaminants presented are included as examples only, and are not presented as being the most hazardous chemicals to which populations may be exposed.

1.5. DOCUMENT ORGANIZATION

This document presents a summary of various factors influencing risk for highly exposed populations. In addition, data sources are explored that can assist exposure/risk assessors in enumerating these highly exposed or susceptible populations.

- Section 2 presents characteristics of the general U.S. population, including sociodemographic, socioeconomic, and health-based factors.
- Section 3 provides population data based on the effects of location of residence.
- Section 4 provides population data based on residential factors.
- Section 5 provides population data based on time in nonresidential buildings.
- Section 6 presents population data for selected recreational activities.
- Section 7 presents occupational population data.
- Section 8 examines cultural and behavioral factors.
- Section 9 provides population data for drinking water and certain food groups.
- Section 10 evaluates population data associated with socioeconomic factors, such as living in poverty.
- Section 11 provides information on accessing information on the Internet useful for identifying potentially highly exposed populations, as well as providing a listing of State environmental protection agencies and a reference source for trade organizations.

Example 1 - Tetrachloroethylene Contamination at a Superfund Site

The Problem:

A Superfund site has caused tetrachloroethylene (also known as perchloroethene) to enter groundwater used as a drinking water source for a community of 10,000 people in Ohio. The risk assessor is interested in knowing if anyone in the affected area may be highly exposed to this chemical.

Identifying the Highly Exposed Populations:

The assessor determines that elevated exposures could occur in two ways:

- High ingestion rates of contaminated water, and
- High background exposures due to activities other than drinking water.

High Ingestion Rate of Contaminated Water:

Using the exposure pathway paradigm in Table 1-2, the assessor identifies three potentially highly exposed populations associated with water consumption: athletes, residents of hot climates, and outdoor workers in hot climates. The groups associated with hot climates will not be of concern, because Ohio has a moderate climate. Athletes may be a concern; using Chapter 6 and Figures 6-1 and 6-2, the assessor learns that approximately 50% of the adult population on a national basis are involved in some form of exercise. Table 1-2 also references the assessor to Table 3-30 in the *Exposure Factors Handbook*, which recommends assuming 6 liters per day (L/day) water consumption for active adults in temperate climates. Clearly, not all of these people exercise aerobically on a regular basis. However, this high percentage suggests that it is reasonable to assume that at least some members of a population of 10,000 will engage in such activities. Therefore, the assessor concludes that some members of the exposed population could have elevated exposures as a result of high water consumption and uses the 6 L/day value to estimate this level of exposure. The nationwide statistics in this document are not adequate for making quantitative estimates of how many people are exposed at this level. Additional sources of information, however, are referenced in Section 11.

High Background Exposures:

The possibility of high background exposures is investigated using Table 1-3. The assessor looks up tetrachloroethylene in this table and sees that a number of people may have elevated background exposures to this chemical (e.g., home repairers or remodelers, house cleaners, painters, and workers at dry cleaning establishments). The assessor then refers to Tables 6-22 through 6-24, 7-7, and Appendix 7B in this document to establish the potentially high background exposed population. Table 6-22 indicates that 48% of people were involved in home improvement/repair during the last 12 months. Table 6-23 indicates that 13 million people paint as a hobby (or X% of population), etc. Accordingly, a high percentage of this population could have elevated background exposures. Tables 5-23 (recommended inhalation rates - select rate based on specific activity level) and 16-13 through 16-18, 16-22, and 16-23 (duration and frequency data of exposure or product use for some categories) from the *Exposure Factors Handbook* can be used. For example, from Table 5-23, one can assume a mean inhalation rate of 1.0 cubic meters per hour (m^3/hr) for a house cleaner who cleans spots on walls or doors based on short-term, light activities. The total exposed time for using specific house cleaning products (all-purpose cleaners) is 64 hours/year (Table 16-16). The duration of performing a specific task (clean spots on walls or doors) is 50 minutes/event (Table 16-15), and the mean frequency for performing this task is 6 times/month. Other tables may be appropriate as determined by the assessor.

Example 2 - Unspecified Soil Contamination in a Residential Community

The Problem:

A residential community is under development in Virginia. For the past 100 years, the land to be developed has been agricultural. Heavy use of pesticides in the past has led to concerns of soil contamination. The risk assessor is interested in knowing whether any subset of the future residents may have high exposures to the soil contaminants.

Identifying the Highly Exposed Populations by Exposure Pathway:

The assessor postulates that elevated exposures to soil contaminants could occur in three ways:

- Inhalation of particulates;
- Dermal contact with soil; and
- Ingestion of soil.

Increased Dermal Contact and Inhalation of Particulates:

Using Table 1-2 , the assessor identifies four potentially highly exposed populations associated with dermal contact with soil: children playing outdoors, gardeners, people engaged in sporting activities (e.g., baseball, softball, golf, football, and soccer), and outdoor workers who may have increased contact with soil (e.g., termite inspectors, highway repairmen, cable repairmen, construction workers, farmers, and nursery workers). These same populations would have elevated exposures via inhalation of suspended soil particles. To characterize the potentially highly exposed groups, the assessor can then use Table 7-7, Appendix 7B, Tables 6-16 and 6-24, and Figure 6-1 in this document. Relevant information in *Exposure Factors Handbook* can be found in Tables 6-2 through 6-8, 6-14, 6-15, 6-16 (exposed skin surface area), and 6-12 (soil adherence value). Duration and/or frequency values for some categories may be obtained from Tables 15-92, 15-93, 15-107, 15-108, and 15-176.

Ingestion of Soil:

Using Table 1-2, the assessor identifies children playing outdoors, pregnant women, migrant workers, and participants in outdoor activities (e.g., gardening, golf, baseball, football, hiking, and camping) as populations who may be highly exposed as a result of soil ingestion. Turning again to Table 1-2, the assessor can use Tables 2-1, 8-2, 8-3, 6-16, 6-19, and 6-24 in this document and Tables 4-11, 4-15, 4-16, 4-22, 15-85, and 4-23 and Section 4.5 for soil ingestion in *Exposure Factors Handbook* as tools to characterize the potentially highly exposed groups. Other tables may be appropriate as determined by the assessor.

1.6. REFERENCES

Adrian, TE; Smith, HA; Calvert, SA; Aynsley-Green, A; Bloom, SR. (1986) Elevated plasma peptide YY in human neonates and infants. Pediatr Res 20:1225-1227.

Agency for Toxic Substances and Disease Registry (ATSDR). (1992) Analysis Paper: Impact of lead-contaminated soil on public health. U.S. Department of Human and Health Services. Atlanta, GA. Agency for Toxic Substances and Disease Registry.

Barltrop, D. (1965) The relationship between some parameters employed in the diagnosis of lead poisoning in childhood with a special reference to the excretion of delta-aminolaevulinic acid. Thesis: University of London.

Behrman, RE; Vaughan, VC; Nelson, WE. (1987) Nelson textbook of pediatrics, 13th ed. Philadelphia: W.B. Saunders Co., pp. 6-33.

Bruhn, CM; Pangborn, RM. (1971) Reported incidence of pica among migrant families. J Am Diet Assoc 58:417-420.

Calabrese, EJ. (1978) Pollutants and high risk groups. New York: John Wiley and Sons, Inc.

Calabrese, EJ. (1985) Toxic susceptibility: male/female differences. New York: John Wiley and Sons, Inc.

Calabrese, EJ. (1986) Age and susceptibility to toxic substances. New York: John Wiley and Sons, Inc.

California Department of Health Services (CDHS). (1991) McFarland child health screening project: 1989. Environmental Epidemiology and Toxicology Branch, California Department of Health Services, Emeryville, CA.

Centers for Disease Control and Prevention (CDC). (1994) Health objectives for the nation: prevalence of overweight among adolescents in the United States, 1988-91. Morbidity and Mortality Weekly Report, November 11, 1994, pp. 818-821. U.S. Public Health Service, U.S. Department of Health and Human Services, Center for Disease Control and Prevention.

Gladtke, E.; Heimann, G. (1975) The rate of development of elimination functions in kidney and liver of young infants. In: Morselli, PL, Garattini, S; Sereni, F. eds. Basic and therapeutic aspects of perinatal pharmacology. New York: Raven Press, pp. 393-403.

Grassman, J. (1995) Incorporation of information on susceptible population into risk assessments (Draft) pp. 1-20.

Greengard, O. (1977) Enzymic differentiation of human liver: comparison with the rat model. Pediatr Res 11:669-676.

Hattis, D; Erdreich, L; Ballew, M. (1987) Human variability in susceptibility to toxic chemicals, a preliminary analysis of pharmacokinetics data from normal volunteers. Risk Anal 7:415.

International Life Sciences Institute (ILSI). (1992) Similarities and differences between children and adults: implications for risk assessment. Washington, DC: International Life Sciences Institute.

Khoury, MJ; Flanders, D; Greenland, S; Adams, MJ. (1989) On the measurement of susceptibility in epidemiol studies. Am J Epidemiol 129:183-190.

Klaassen, CD; Amdur, MO; Doull, J. eds. (1996) Casarett and Doull's toxicology: the basic science of poisons, 5th ed. New York: McGraw-Hill.

Kuczmarski, J. (1994) Increasing prevalence of overweight among U.S. adults. JAMA 22(3):205-211.

Lorenz, JM; Kleinman, LI. (1988) Ontogeny of the kidney. In: Tsang, RC; Nichols, BL, eds. Nutrition during infancy. St. Louis, MO: C.V. Mosby, pp. 58-85.

Mitchell, R; Dawson, B. (1973) Educational and social characteristics of children with asthma. Arch Dis Child 48:467-471.

Montgomery, LE; Carter-Pokras, O. (1993) Health status by social class and/or minority status: implications for environmental equity research. Toxicol Ind Health 9(5):729-773.

Morselli, PL. (1989) Clinical pharmacology of the perinatal period and early infancy. Clin Pharmacokinet 17:13-28.

Morselli, PL; Franco-Morselli, R; Bossi, L. (1980) Clinical pharmacokinetics in newborns and Infants: age-related differences and therapeutic implications. Clin Pharmacokinet 5:485-527.

National Academy of Science (NAS). (1991) Infant outcomes. In: Nutrition during lactation. Washington, DC: National Academy Press.

National Research Council (NRC). (1993) Pesticides in the diets of infants and children. Washington, DC: National Academy Press.

Neuhauser, MLS. (1994) Nutrition during pregnancy and lactation. In: Mahan, KL; and Escott-Stump, S.; eds. Food, nutrition and diet therapy. 9th ed. Philadelphia, PA: WB Saunders Company.

Omenn, GS. (1984) Risk assessment, pharmacogenetics, and ecogenetics. In: Omenn, GS; Gelboin, HV, eds. Banbury Report: genetic variability in responses to chemical exposures. Cold Spring Harbor Laboratory, pp. 3-13.

Otten, MW; Teutsch, SM; Williamson, DF; Marks, JS. (1990) The effect of known risk factors on the excess mortality of black adults in the United States. JAMA 263(6):845-850.

Rane, A; Lunde, PKM; Jalling, B; Yaffe, SJ; Sjoqvist, F. (1971) Plasma protein binding of diphenylhydantoin in normal and hyperbilirubenemic infants. Pediatr Pharmacol Ther 78:877-882.

Rios, R; Poje, GV; Detels, R. (1993) Susceptibility to environmental pollutants among minorities. Toxicol Ind Health 9(5):797-820.

Romero, P; Bamett, PG; Midtting, JE. (1989) Congenital anomalies associated with maternal exposure to oxydemeton-methyl. Environ Res 50(2):256-261.

Romieu, I; Carreon, T; Lopez, L; Palazuelos, E; Rios, C; Manuel, Y; Hernandez-Avila, M. (1995) Environmental urban lead exposure and blood lead levels in children of Mexico City. Centro Panamericano de Ecologia Humana y Salud, Organizacion. Panamericana de la Salud, Mexico City, Mexico. Environ Health Perspect 103(11):1036-1040.

Sexton, K; Olden, K; Johnson, BL. (1993) Environmental justice: the central role of research in establishing a credible scientific foundation for informed decision making. Toxicol Ind Health 9(5):685-727.

Starfield, B. (1982) Family income, ill-health, and medical care of U.S. children. J Public Health Policy 3:244-259.

Starfield, B; Budetti, PP. (1985) Child health status and risk factors. Health Serv Res 19:817-886.

Sutton, PM; Athanasoulis, M; Flessel, P; Guirguis, G; Haan, M; Schlag, R; Goldman, LR. (1995) Lead levels in the household environment of children in three high-risk communities in California. Environ Res 68(1):45-57.

U.S. Bureau of the Census. (1995) Statistical abstract of the United States: 115th ed. U.S. Department of Commerce, Bureau of the Census, Washington, DC.

U.S. Department of Labor (U.S. DOL). (1994) Revisions in the current population survey effective January 1994. Employment and earnings. Washington, DC: U.S. Department of Labor, Bureau of Labor Statistics.

U.S. Environmental Protection Agency. (1985) Methods for assessing exposure to chemical substances, vol. 4. Methods for enumerating and characterizing populations exposed to chemical substances. Office of Toxic Substances, Washington, DC. EPA/560/5-85-004.

U.S. Environmental Protection Agency. (1989a) Exposure factors handbook. National Center for Environmental Assessment, Office of Research and Development, Washington, DC. EPA/600/P-95/002Bc.

U.S. Environmental Protection Agency. (1989b) Populations of potential concern in chemical exposure and risk assessment. Office of Health and Environmental Assessment. Washington, DC. Environmental Criteria and Assessment Office, Research Triangle Park, NC.

U.S. Environmental Protection Agency. (1989c) Risk assessment guidance for Superfund, Vol. 1. Human health evaluation manual (part A). Prepared by the Office of Health and Environmental Assessment, Environmental Criteria Assessment Office, Research Triangle Park, NC, for the Office of Emergency and Remedial Response, Office of Solid Waste and Emergency Response, Washington, DC. EPA/540/1-89/002.

U.S. Environmental Protection Agency. (1992a) Guidelines for exposure assessment. Federal Register 57(104):22888-22896.

U.S. Environmental Protection Agency. (1992b) A citizen's guide to radon. Office of Air and Radiation, U.S. Environmental Protection Agency, Washington, DC.

U.S. Environmental Protection Agency. (1997) Exposure factors handbook. National Center for Environmental Assessment, Office of Research and Development, Washington, DC. EPA/600/P-95/002Fa,b,c.

Vermeer, DE; Frate, DA. (1979) Geophagia in rural Mississippi: environmental and cultural contexts and nutritional implications. Am Clin Nutr 32:2129-2135.

Weiss, KB; Gergen, PJ; Crain EF. (1992) Inner-city asthma-the epidemiology of an emerging U.S. public health concern. Chest 101(6):362S-371S.

Wendroff, AP. (1990) Domestic mercury pollution. (Scientific letter of correspondence to the editor). Nature 347:623.

Wester, RC; Maibach, HI. (1982) Percutaneous absorption: neonate compared to the adult. pp. 3-15 in Banbury Report No. 11: Environmental factors in human growth and development. Hunt, VR; Smith, MK; Worth, D., eds. New York: Cold Spring Harbor Laboratory.

Table 1-1. Populations Potentially at Risk of Exposure to Specific Chemical(s) of Concern

Population/Activities	Chemical(s) of Potential Concern
Infant and Child Activities	
Infant breastfeeding	BHC-beta, BHC-gamma (lindane), cadmium, carbon disulfide, chlordane, DDD, DDE, DDT, 1,4-dichlorobenzene, dichloromethane, dieldrin, dioxin, heptachlor, heptachlor epoxide, hexachlorobenzene, lead, mercury, tetrachloroethene, PCBs
Normal outdoor play	Highly to moderately adsorptive substances (e.g., asbestos, beryllium, copper, lead, mercury, silver, thallium, zinc)
Dirt biking	Highly to moderately adsorptive substances (e.g., asbestos, beryllium, copper, lead, mercury, silver, thallium, zinc)
Adult Activities	
Household activities:	
Gardening	Arsenic, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, cadmium, chrysene, coal tars, creosote, dibenzo(a,h)anthracene, dieldrin, dioxin, heptachlor, lead, selenium
Auto care	Ammonia, benzene, dichlorodifluoromethane, dichloromethane, nitrobenzene, 1,1,1-trichloroethane, trichlorofluoromethane, zinc
Home repair/remodeling	Ammonia, arsenic, bis(2-chloroethyl)ether, bis(chloromethly)ether, coal tars, cresol, dichlorodifluoromethane, dichloromethane, diethyl phthalate, dimethyl phthalate, di-n-butyl phthalate, lead, mercury, methyl ethyl ketone, methyl isobutyl ketone, pentachlorophenol, tetrachloroethene, toluene, xylene, zinc
Sports:	
Hunting (deer and waterfowl)	Deer: pesticides Waterfowl: substances with high to moderate bioaccumulation potential
Fishing	Any substance with high to moderate bioaccumulation potential
Target shooting	Lead
Hobbies:	
Arts and crafts	Ammonia, benzene, bis(2-ethylhexyl)phthalate, chloroethene, creosote, dichloromethane, diethyl phthalate, dimethyl phthalate, di-n-butyl phthalate, lead, mercury, methyl ethyl ketone, methyl isobutyl ketone, phenol, 1,1,1-trichloroethane, 2,4,6-trichlorophenol, toluene, zinc
Film developing	Ammonia, cyanide, dichlorodifluoromethane, 1,1,1-trichloroethane, trichloroethene, trichlorofluoromethane, toluene, xylene
Furniture refinishing	Benzene, bis(2-ethylhexyl)phthalate, dichloromethane, diethyl phthalate, dimethyl phthalate, di-n-butyl phthalate, methyl ethyl ketone, methyl isobutyl ketone, toluene, xylene

(continued)

Table 1-1. Populations Potentially at Risk of Exposure to Specific Chemical(s) of Concern (continued)

Population/Activities	Chemical(s) of Potential Concern
Occupations	
Agricultural workers	Pesticides
Blacksmiths	Cyanide, PAHs
Chimney sweeps	Coal tars
Commuters	Particulates, carbon monoxide, benzene, formaldehyde, criteria pollutants
Domestics/housecleaning	Ammonia, anthracene, bis(2-chloroethyl)ether, di-n-butyl phthalate, 1,4-dioxane, ethylene oxide, mercury, phenol, styrene, tetrahydrofuran, tetrachloroethene, toluene, trichloroethane, xylene, zinc
Electrical equipment repair	PCBs
Exterminators	Pesticides
Firefighters	Cyanide
Jewelers	Lead, nickel
Laboratory technicians	Acrolein, arsenic, asbestos, bis(chloromethyl)ether, benzidine, benzoic acid, chloroethene, chloromethane, 2,4-dinitrophenol, 1,4-dioxane, mercury, pyrene, silver, trichloroethene, trichloromethane
Painters/paint store employees	Benzene, dichloromethane, nickel, tetrachloroethene, toluene, trichloromethane
Road pavers and roofers	Coal tars, PAHs
Service station attendants	Benzene, lead
Welders	Chromium, nickel
Adult Risk-associated Behavior	
Alcohol consumption	Lead, trichloroethene, trichloromethane, pesticides, PCBs
Smoking/environmental tobacco smoke	Asbestos, benzene, beryllium, cadmium, chrysene, cyanide, lead, nickel, trichloroethene, PAHs
Substance abuse	Pesticides, PCBs
Residential (housing characteristics)	
Basements	Radon
Kerosene heat	Carbon monoxide, nitrous oxide
Inner city location	Lead, cockroach antigen, benzene, criteria pollutants
Private wells	Pesticides, metals, solvents, mocrobials

Source: U.S. EPA, 1989c; U.S. EPA, 1992.

Table 1-2. Identifying Potentially Highly Exposed Populations on the Basis of Exposure Pathway

Exposure Pathway	Potentially Highly Exposed Population	Tables on Sociodemographics from this Document	Tables on Factor Values from EFH
Water Ingestion			3-30
	Athletes	6-24	3-27, 3-30
	Residents of Hot Climates	2-4	
	Outdoor Activities in Hot Climates		3-27, 3-28
	Recreational Participants in Hot Climates/Weather	6-24	
Soil Ingestion			4-23
	Children	2-1	4-15, 4-22
	Pregnant Women	8-2	Section 4.5
	Migrant Workers	8-3	
	Outdoor Activities (e.g., sports, work, gardening)	6-24 6-16, 6-19	4-11, 4-15, 4-16, 15-85
Inhalation			5-23
	Athletes	6-24	
	Children	2-1	5-25
	Outdoor Sports Participants (e.g., baseball, softball, football, soccer)	6-24	5-26, 5-27, 15-85
	High Activity Level Workers (e.g., farmers)	7-1, 7-3, 7-6, 7-7, Appendix 7B, 7C	
Dermal Contact with Soil			6-14, 6-16
	Children	2-1	6-12, 15-108
	Home Gardeners	6-16	15-92
	Outdoor Sports Participants (e.g., golf, baseball, football, soccer, hiking, camping, running/jogging, softball)	6-24 Figure 1	6-2, 6-8, 15-85, 15-93
	Outdoor Occupations (e.g., pesticide applicators, landscapers, highway repairers, farmers, construction workers)	7-5, 7-6, 7-7, Appendix 7B	15-107
Fish Ingestion			10-81 thru 10-85
	Fishers	6-1, 6-3	
	Eskimos	2-4, 2-10	
	Native Americans	2-4, 2-10	
Dermal Contact with Water			6-14, 6-16
	Fishers, occupational and recreational	7-6, 7-7	6-2 thru 6-8, 10-83, 10-84
	Aquatic Sportsmen (e.g., swimmers, boaters, water skiers, jet skiers)	6-24	6-14, 6-16, 15-176

Table 1-3. Identifying Potentially Highly Exposed Populations on the Basis of Hazardous Substance
(Hazardous Substances from 1997 EPA/ATSDR Priority List of Hazardous Substances)

Hazardous Substance	Potentially Highly Exposed Population[a]	Relevant Tables in this Document	Relevant Tables in Exposure Factors Handbook
Arsenic	***Activities:***		
	Children playing outdoors (esp. on wood treated structures or near contaminated soil)	2-1	5-25, 6-14, 15-59, 15-60
	Drinking well water contaminated by natural sources	9-3	3-30
	Gardeners	6-16	4-15, 4-16, 6-16, 15-61
	Living near metal smelters		
	Occupations:		
	Metal smelters, semiconductor manufacturers, pesticide manufacturers, farm workers, refinery workers	7-5, 7-6, 7-7, Appendix 7B, 7C	5-23
Lead	***Activities:***		
	Children playing outdoors (esp. near roads or freeways)	2-1	5-25, 6-14, 15-59, 15-60
	Dirt bikers		4-23, 5-22, 6-2 thru 6-5, 6-14
	Gardeners	6-16	4-15, 4-16, 15-61, 6-16
	Home repairers/remodelers	6-23	
	Target shooters	6-23	
	Arts and crafts hobbyists	6-23	
	Occupations:		
	House cleaners, service station workers	7-5, 7-6, 7-7, Appendix 7B, 7C	16-2 thru 16-5, 16-23, 16-28
	Behavior Patterns:		
	Pica	8-2, 8-3	4-23
Mercury, Metallic	***Activities:***		
	Children playing indoors (as a result of cultural/religious practices)	2-1	15-79
	Occupations:		
	Chlorine and caustic soda production workers, cosmetic producers, dental personnel, electroplators, explosives manufacturers, felt makers and leather tanners, grinding machine operators, hazardous waste site personnel, ink manufacturers, laboratory personnel, manufacturers of batteries, fluorescent lamps, mercury vapor lamps, switches, rectifiers, metallurgists, miners and processors of cinnabar, gold, silver, copper, zinc, paint and pigment manufacturers, painters, paper millers, pesticide/fungicide production and application workers, pharmaceutical producers, plumbers	7-3, 7-4, 7-7 Appendix 7B, 7C	16-26
	Behavior Patterns:		
	Cultural practices (Hispanic population)	2-1	
Vinyl Chloride (Other names: chloroethylene, chlorethane, monochloroethylene, ethylene monochloride, monochloroethane, VCM, vinyl chloride monomer)	***Occupations:***		
	Plastics manufacturers, vinyl chloride and PVC manufacturers, especially autoclave cleaners in PVC production plants	7-7, Appendix 7B, 7C	16-26

Table 1-3. Identifying Potentially Highly Exposed Populations on the Basis of Hazardous Substance (Hazardous Substances from 1997 EPA/ATSDR Priority List of Hazardous Substances) (continued)

Hazardous Substance	Potentially Highly Exposed Population[a]	Relevant Tables in this Document	Relevant Tables in Exposure Factors Handbook
Benzene (Other names: benzol, carbon oil, coal tar naphtha, cyclohexatriene, phenyl hydride, pyrobenzole)	***Activities:*** Arts and crafts hobbyists	6-23	16-26
	Occupations: Gasoline storage personnel, shipment and retail operations workers, chemical manufacturers, plastics and rubber manufacturers, shoe manufacturers, printers, petroleum refinery personnel, workers in recovery plants for coke oven by-products, artists, house cleaners, gasoline workers	7-3, 7-4, 7-7, Appendix 7B, 7C	16-23, 16-28
	Behavior Patterns: Smokers	8-6, 8-7	15-141
Polychlorinated Biphenyls (PCBs), including Arochlor 1254 and 1260	***Activities:*** Hunters Fishers	6-6, 6-7 6-2	11-6 10-83, 10-84, 10-85
	Occupations or Hobbies: Electricians, electric cable repairpersons, electroplators, emergency response workers, firefighters, hazardous waste haulers or site repair workers, maintenance cleaners, metal finishers, pavers and roofers, pipefitters/plumbers, timber products manufacturers, transformer/capacitor repairers, and personnel involved in waste oil processing	7-3, 7-4, 7-7, Appendix 7B, 7C	
Cadmium	***Activities:*** Jewelery hobbyists	6-23	
	Occupations: Alloy makers, aluminum solder makers, ammunition makers, auto mechanics, battery makers, bearing makers, braziers and solderers, cable and trolley wire makers, cadmium platers, cadmium vapor lamp makers, pottery makers, copper-cadmium alloy makers, electrical condenser makers, electroplaters, engravers, farm workers, glass makers, incandescent lamp makers, jewelers, lithographers, lithopone makers, mining and refining workers, paint makers, paint sprayers, pesticide makers, pharmaceutical workers, photoelectric cell makers, pigment makers, plastic products makers, metal sculptors, solder makers, textile printers and cadmium alloy and cadmium-plate welders	7-3, 7-4, 7-7, Appendix 7B, 7C	
	Behavioral Patterns: Smokers	8-6, 8-7	15-141
Polycyclic aromatic hydrocarbon (PAH) compounds (Other names: Acenaphthene, acenaphthylene, anthracene, benz(a)anthracene, benzo(a)pyrene, benzo(b) fluoranthene, benzo(ghi)perylene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,2-cd)pyrene, phenanthrene, pyrene Dibenz[a,h]anthracene)	***Activities:*** Charcoal grillers Fishers Furniture refinishing hobbyists	 6-2 6-23	15-34 10-83, 10-84, 10-85
	Occupations: Aluminum workers, asphalt workers, carbon black workers, chimney sweeps, coal tar production plant workers, coal-gas workers, coke oven workers, fishermen, graphite electrode workers, machinists, auto and diesel engine mechanics, municipal trash incinerators, printers, road workers, roofers, smoke houses, steel foundry workers, tire and rubber manufacturing workers, workers exposed to creosote such as carpenters, farmers, railroad workers, tunnel construction workers, and utility workers. workers using high-temperature food fryers and broilers	7-3, 7-4, 7-7, Appendix 7B, 7C	

Table 1-3. Identifying Potentially Highly Exposed Populations on the Basis of Hazardous Substance (Hazardous Substances from 1997 EPA/ATSDR Priority List of Hazardous Substances) (continued)

Hazardous Substance	Potentially Highly Exposed Population[a]	Relevant Tables in this Document	Relevant Tables in Exposure Factors Handbook
Chloroform (Other names: trichloromethane, methenyl chloride, methane trichloride, methyl trichloride, formyl trichloride)	***Activities:*** Swimmers Drinking chlorinated water Showering in enclosed stalls ***Occupations:*** Chloroform manufacturers, fluorocarbon-22 and ethylene dichloride manufacturers, internal combustion engine industries, pesticide manufacturers, pulp and paper millers, food processing industry and paint store workers, pharmaceutical manufacturing plants, sewage treatment plants personnel	6-24 7-3, 7-4, 7-7, Appendix 7B, 7C	15-18, 15-65, 15-66, 15-67 15-19, 15-20, 15-21, 15-22, 15-23 6-26
DDT, P'P' (other name: dichlorodiphenyltrichloroethane)	Banned in the U.S. in 1972, however residues can still be detected on agricultural products and other food products ***Occupations:*** Farmers, nursery personnel may be exposed to residues still found in soil	 7-3, 7-4, 7-7, Appendix 7B, 7C	
Trichloroethylene (other names: TCE, trichloroethene, ethylene trichloride, 1-chloro-2,2-dichloroethylene, 1,1-dichloro-2-chloroethylene, 1,1,2-trichloroethylene, TRI)	***Activities:*** Arts and crafts hobbyists Bathing, laundering or cooking with contaminated water ***Occupations:*** Metal degreasing operators, municipal and hazardous waste incinerator workers, manufacturers of adhesive glues, disinfectants, pharmaceuticals, dyes, perfumes, soaps, paints, and coatings, workers in chemical industries that manufacture polyvinyl chloride, pentachoroethane, and other polychlorinated aliphatic hydrocarbons, flame retardant chemicals and insecticides, mechanics, oil processors, printers, resin workers, rubber cementers, shoe makers, textile and fabric cleaners, tobacco denicotinizers, varnish workers, and some dry cleaners	6-23 9-3 7-3, 7-4, 7-7, Appendix 7B, 7C	15-18, 15-19 to 15-21, 15-24, 15-89 15-99
Chromium (hexavalent)	***Activities:*** Living on landfill derived from chromium-containing soil Children playing outdoors (esp. near roadways or contaminated landfill) ***Occupations:*** Welding of alloys and steel, chrome electroplating, paints and pigments manufacture, chemical manufacture, industrial cooling towers using chromate chemicals as rust inhibitors , chrome alloy production, textile manufacturing, photoengraving, copier servicing, leather tanning, and airborne emissions from incineration facilities	2-1 7-3, 7-4, 7-7, Appendix 7B, 7C	15-25, 15-59, 15-60, 6-14
Hexachlorobutadiene (Other names: HCBD, perchlorobutadiene, Dolen-Pur)	***Occupations:*** Manufacturers of rubber compounds and lubricants, and manufacturers of chemicals such as tetrachloroethylene, trichloroethylene and carbon tetrachloride.	7-7	
Chlordane, including aldrin, dieldrin, and hepachlor (Trade names: Velsicol-1068, Octachlor, Chlorkil, Ortho-chlor, Dowchlor, Gold Crest C-100, Topiclor 20)	***Activities:*** Living in homes previously treated for termite infestation Eating food prepared from plants grown on chlordane-treated fields and the fat of meat or milk from animals that eat grass from chlordane-treated fields ***Occupations:*** Chlordane pesticide manufacture for export, or chlordane cleanup workers (Chlordane has been banned from commercial use in the U.S)	 7-3, 7-4, 7-7, Appendix 7B, 7C	16-31, 16-32 5-23, 6-2, 6-3, 6-4, 6-5

Table 1-3. Identifying Potentially Highly Exposed Populations on the Basis of Hazardous Substance (Hazardous Substances from 1997 EPA/ATSDR Priority List of Hazardous Substances) (continued)

Hazardous Substance	Potentially Highly Exposed Population[a]	Relevant Tables in this Document	Relevant Tables in Exposure Factors Handbook
Tetrachloroethylene (Other names: tetrachloroethene)	***Activities:***		
	House repairers or remodelers	6-23	
	Use of spot removers, or exposure to recently dry-cleaned fabrics		
	Possible well water contamination		
	Auto repair	6-23	
	Hobbyists using paint removers and wood cleaners	6-23	
	Occupations:		
	Dry-cleaning workers, machinists, plastic extruders, and electronic assemblers, or workers manufacturing consumer products containing tetrachlorethylene, house cleaners, painters	7-3, 7-4, 7-7, Appendix 7B, 7C	

a Potential highly exposed populations may include these groups, but are not limited to these groupings.

Source: Adapted from Agency for Toxic Substances and Disease Registry, Case Studies in Environmental Medicine (1990-1993).

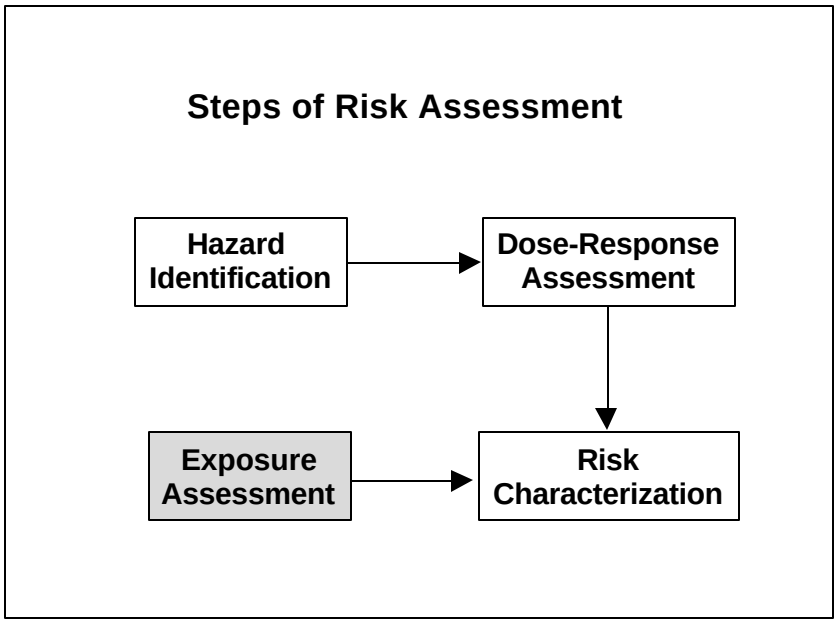

Figure 1-1. Risk Assessment Paradigm

Source: U.S. EPA, 1992.

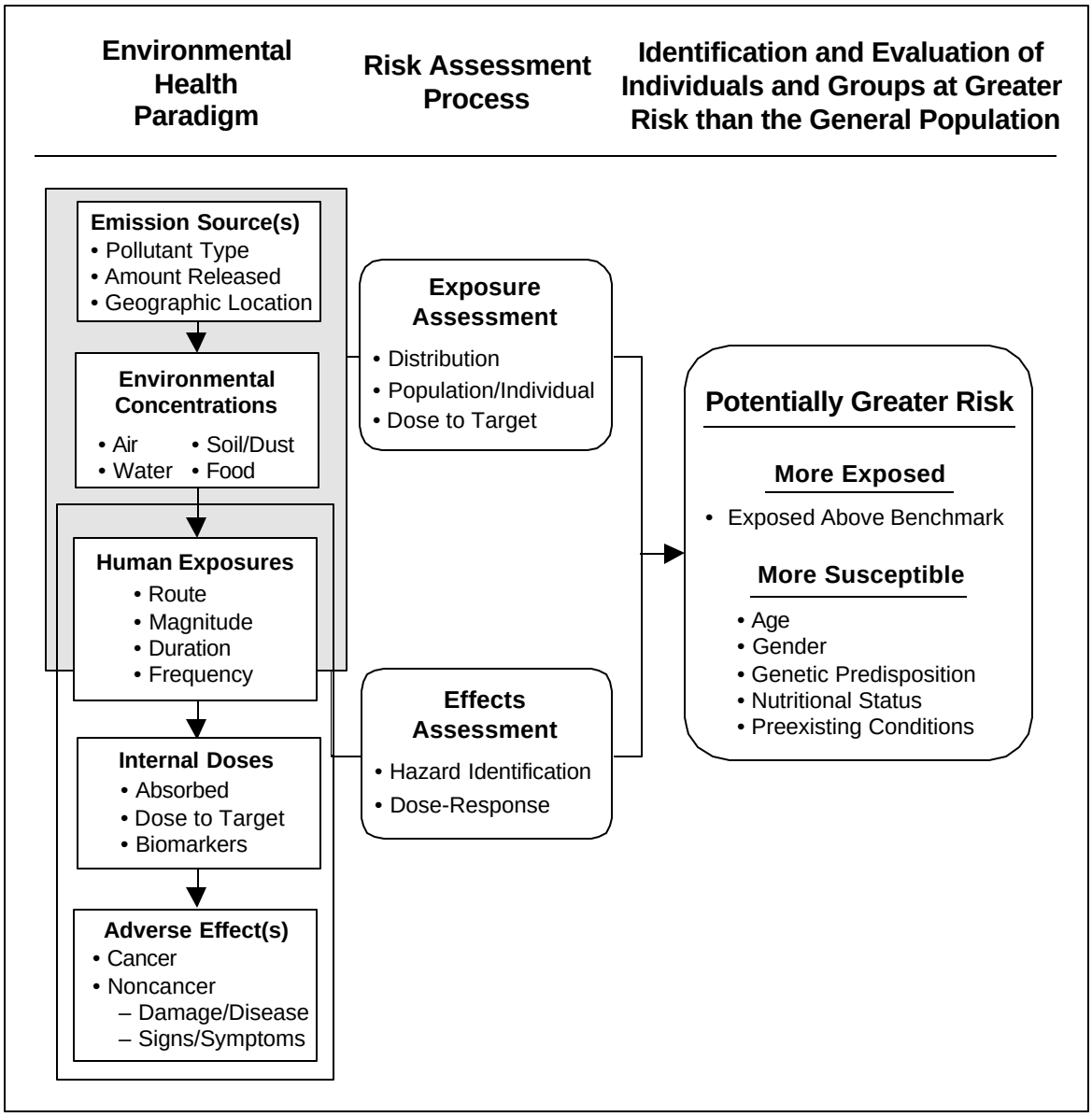

Figure 1-2. Methodological Approach for Identification and Evaluation of Populations Potentially at Greater Risk

Source: Sexton et al., 1993

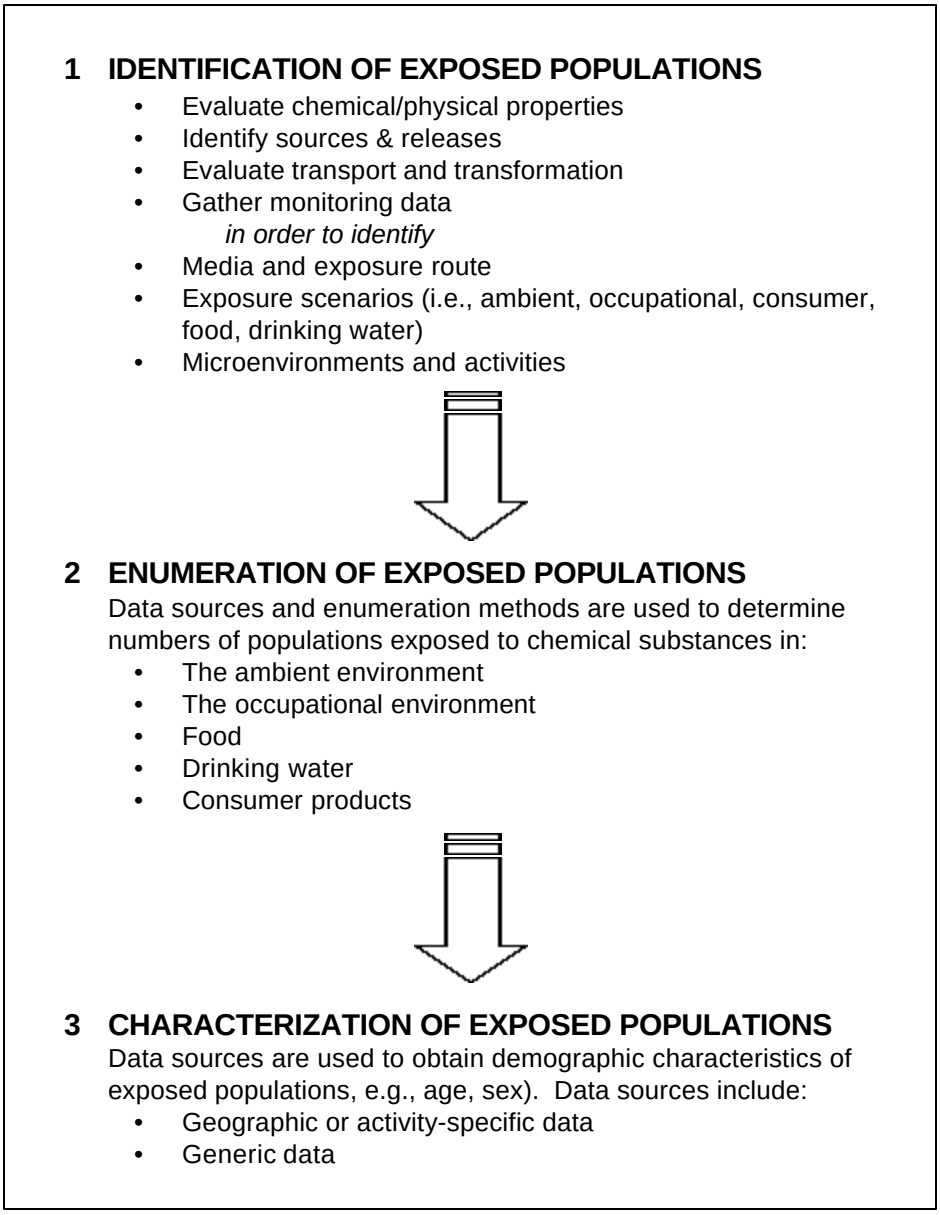

Figure 1-3. The Three-Stage Framework for Identifying, Enumerating, and Characterizing Populations Exposed to Chemical Substances

Source: U.S. EPA, 1992b.